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Developing Technical Vocabulary and Scientific Writing Skills of English Language Learners in General Education Science Classrooms

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Abstract

Through weekly tutoring sessions with a 1:1 teacher to ESL student ratio different instructional techniques and strategies were tested for their practicality, applicability, and success for developing the vocabulary comprehension and scientific writing skills. The sessions served a two-fold purpose: (1) to test various strategies and techniques relevant to the topic, and (2) to provide additional support to an at-risk student that cannot be provided by the school. The student participant was a 10th grade ESL student, who has been in the U.S. for 8 years, yet continues to struggle with science, particularly with vocabulary and writing skills. This study identified specific student weaknesses in science and used techniques adapted from previous studies with ESL students to strengthen such weaknesses. Techniques and strategies tested include, vocabulary introduction accompanied by teacher-constructed graphic/visual aids, vocabulary discussions, and summary framing used in writing exercises. The results of this study show a marked improvement in both vocabulary usage and scientific writing skills, as seen through review of the student's labs completed prior to and during the study.

Chapter One: Introduction

"In principle, the United States is a monolingual country where English is indisputably the language of all major institutions" (Gonzalez, 1990, p.16), yet the harsh reality is that the United States is a culturally and linguistically diverse population, where more than 17 percent of the country speaks a language other than English in their home, up from 14 percent in 1990 and 11 percent in 1980. The four major language groups in the United States are Spanish (28.1 million), other Indo-European languages, including, but not limited to German, Dutch, French, and Italian (10 million), Asian and Pacific Island languages (7 million), and all other languages, including, but not limited to Uralic languages, Arabic, Hebrew, and African languages (1.9 million). The number of non-native English speaking students entering our schools is rapidly on the rise, and it is projected that by 2050 Hispanics alone will equate for one quarter of our population (U.S. Census Bureau, 2000).

Problem Statement

English language learners (hereafter ELLs) currently account for more than 10 percent of the American school-age population and educating this special population is the single greatest challenge in American schools today (Rice, Pappamihiel, & Lake, 2004). As secondary science teachers we face an even greater challenge in developing the scientific literacy of ELLs mainstreamed into our classrooms. The technical vocabulary and specialized scientific writing skills employed in our classrooms demand an even greater knowledge and command of the English language from all students, not just ELLs, but the struggle for these students is surely greater.

Significance of the Problem

Between 1950 and 1960 the United States witnessed an increase of more than 50% in the Spanish-speaking population from 2.3 million to 3.5 million, the majority of which were non-native speakers of English. In response to these numbers the federal government began funding the first bilingual education programs in American public schools through Title VII of the Elementary and Secondary Education Act of 1965, also known as the Bilingual Education Act of 1968. The original design was to provide assistance to public schools with the purpose of setting up bilingual education programs for low-income, non English speaking students in the United States. Two major points to consider when addressing the Bilingual Education Act of 1968 are: (a) it was intended to fund both elementary and secondary programs, and (b) the majority of all programs "designed, funded, and implemented" (Faltis & Arias, 1993, p. 7) by the Act have been in elementary schools. Furthermore, the majority of all research in bilingual education is focused in the elementary schools, and has severely overlooked the concerns and issues involving upper-middle school and high school teachers and students (Faltis & Arias, 1993). This is a serious concern for secondary teachers of all grades and subjects.

Fortunately, with the 1990's came a greater concern for scientific literacy for all students, regardless of race, ethnicity, gender, or native language. The Benchmarks for Science Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) defined scientific literacy, the nature of science, the need for scientific inquiry, and designed national curriculums for science teaching with "science for all" (p.20) at the heart of each agenda. The National Science Education Standards (1996) stipulate in the most detailed fashion that the goal of science education in the coming decades is to provide "all students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science . . . the opportunity to obtain high levels of scientific literacy" (p. 20). In 2001, President Bush's No Child Left Behind Act (U.S. Department of Education, 2002) was passed and applied to America's public schools, which Rice et al. (2004) suggest made it almost impossible for school districts and teachers in the U.S. to ignore their "responsibilities to provide appropriate assistance to all students, including ELLs" (p. 121) in becoming scientifically literate. As a result of this accountability movement ELLs must be held to the same high standards as native English speaking students in the science classroom, and be provided equitable opportunities to learn science in a manner that is understandable and consistent with the national standards. Scientific literacy is the key factor behind providing equitable opportunities to ELLs in the general education classroom, but it must not include "watered-down instruction, which reduces learning to rote memorization of vocabulary and lower order thinking for these students" (Rice et al., 2004, p.122).

Purpose

The purposes of this research are both broad and narrow in scope, yet they all focus on one target, success. The main question guiding this research is: What can secondary science teachers do to promote greater success for ELLs in the general education science classroom? This question was explored by focusing on: (a) what the major struggles are for ELLs in becoming scientifically literate, and (b) how effective specific strategies are in developing the scientific vocabulary and scientific writing skills of ELLs.

Rationale

During my student teaching experience I personally faced the challenge of teaching science to ELLs, specifically earth science; a scientific concentration laden with abstract concepts, unfamiliar technical vocabulary, and mixed word meanings. The school, and district, I was teaching in has a large community of foreigners, most of which are non-native English speakers, predominantly Eastern European, Hispanic, and Asian. For many of these students English is not spoken in their homes and the school environment represents the primary environment in which these students have contact with English.

From the three Regents earth science classes I taught I had two students whose native languages were a language other than English (Turkish and Ukrainian), and as an inexperienced teacher I had no background for dealing with this situation. It wasn't even until the last week of my placement that I thought about developing some strategies to help these students succeed in earth science, and at that point it was almost too late for me, as I would be moving on shortly. In one of my last days of student teaching our school was holding formal parent-teacher conferences, and it was during these conferences that I had the opportunity of meeting with one of the ELL's parents. To highlight a previous point, the parents did not speak a word of English, even though they had been in America for eight years, and a translator had to be present for the conference. During the conference the mother of the student expressed her concern for her child's ability to grasp the concepts and vocabulary specific to the science classroom, and asked if there was any support available at the school for her child outside of what was already being done for her (the student was receiving support from an ESL, English as a Second Language, teacher in the form of resource room once a week). As I was looking ahead at my own future this was the defining moment when the light bulb flickered, and I realized there was something more that I could do to help this student succeed.

Definition of Terms

For the purpose of this research ELLs are defined as any students whose native language is one other than English, or those students who primarily speak a language other than English at home, and may also be referred to as ESL students (English as a Second Language). Alternately, non-native English speakers may be defined as any person, school-aged or not, whose primary spoken language is any language other than English.

Summary

Presently, American schools are terribly deficient in providing adequate support and instruction for ELLs in secondary schools, and educational research on secondary ELL programs, literacy strategies, and struggles remains just as deficient (Case, 2002; Jaipal, 2001; Faltis & Arias, 1993). This research intends to investigate the struggles of ELLs in gaining greater scientific literacy, and aims to develop successful strategies designed to overcome these struggles, while promoting success based on data derived from writing samples, test and lab assessments, and student perceptions and feedback.

Chapter Two: Literature Review

Scientific Literacy

Contemporary definitions of scientific literacy may vary, but most acknowledge the need to "broaden the traditional focus on technical conceptions and terminology" (Hand, Prain, Lawrence, & Yore, 1999, p. 1021), while focusing on communication skills in scientific debate, reasoning skills, unifying concepts, and the ability to construct scientific meaning. Hand et al. (1999) use a broader definition of scientific literacy encompassing "the interdependent dimensions of the nature of science and scientific inquiry, reasoning and epistemological beliefs in the construction, dissemination, and application of scientific knowledge" (p. 1032).

The National Science Education Standards (NRC, 1996) defines scientific literacy in conjunction with this broader view as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p. 22). The National Education Standards defines a scientifically literate person as one who can "engage intelligently in public discourse and debate" (p. 13), can "construct explanations of natural phenomena, test these explanations in many different ways and communicate their ideas to others" (p. 20), "can ask, find, or determine answers to questions derived from curiosity about everyday experiences" (p. 22), and as individuals who "will display their scientific literacy in different ways, such as appropriately using technical terms, or applying scientific concepts and processes" (p. 22).

Jaipal (2001) suggests that scientific literacy is characterized by discourses of reasoning including making predictions from observations, thesis-evidence conclusions, and problem solving, where language is used for the functions of comparing and contrasting, hypothesizing, inferring, generalizing, classifying, and explaining. Others broaden the scope of scientific literacy to include understandings of mathematics and technology (AAAS, 1993), the history of science ideas, and the role of science and technology in the personal life and society (Bybee, 1995).

The definition of scientific literacy is broad, but the overarching elements found in every definition focus upon communication skills; the ability of the scientifically literate person to express their thoughts, ideas, observations, and explanations of natural phenomena and the nature of science to others through both oral and written language, whether it be in the science classroom, in public debate, or private discourse.

Scientific Vocabulary: A Specialized Language

For most native English speakers the language tasks demanded of them in the science classroom are rather straightforward; they must learn new vocabulary necessary in framing, using, and understanding new concepts. For ELLs, who may have as little as a few months worth of English language instruction, the challenge of the science classroom is much greater. For most of these students they are still acquiring basic literacy skills in English, and at the same time being asked to: (a) locate new information in science texts, (b) interpret and apply the new information, (c) and involve in inquiry-based tasks (asking questions, making predictions, describing observations, and creating explanations). ELLs are not only called upon to gain command of the spoken English language in the scientific context, but also be able to read and write in a scientific context (Carrier, 2005).

Linguistically, the most important element of language the ELL requires is vocabulary, and the abundance of new terms introduced in the science class for these students poses particular problems. Specialized vocabulary (words such as tectonic and porosity) are closely tied to the specific content of science, and remain as a central feature to most science textbooks. Also, in many science textbooks abstract ideas and concepts are linked together and logically developed through the use of many different linguistic devices (repetition of key words, paraphrasing or use of semantically similar terms, and the use of logical connectors, such as however, consequently, and for example). For many ELLs, use of these logical connectors in scientific reasoning creates misunderstandings and confusion (Kessler & Quinn, 1995).

Scientific language is often characterized by elaborated grammatical patterns that consist of a nominal group (noun) connected by a verbal group (verb), whereas non-scientific language is often characterized by simplified structure construed around a clause consisting of a nominal group, verbal group, adjectives, adverbs or prepositions and conjunctions. A group is an expanded word around a noun or verb. The following examples (adapted from Jaipal, 2001, p. 5) express the differences between the simplified structure and the scientific structure of a sentence with practically the same meaning.

Simplified: The girl swam very fast so she was tired.

clause conjunction clause

Scientific:

The fast swim of the girl across the pool resulted in tiredness

Nominal group verbal group nominal group

The above simplified clauses are transformed in the scientific language from a process (first clause) and a quality (second clause) into nominal groups as part of a single clause. Furthermore, during science instruction such sentence structures in this elaborated grammatical pattern are likely to be unfamiliar to both ELL and native English speaking students (Jaipal, 2001). The disadvantage of the ELL compounds with the introduction of unfamiliar and specialized terms and vocabulary found in this sentence structure.

Another obstacle ELLs deal with, in respect to vocabulary, is the multiple meanings a single term can carry in the English language based upon the context it is used. Terms used in the science class may often carry a social context, as well as their scientific/academic context. For example the word "force" may be used in several different ways as both a noun and a verb with such divergent meanings as: push(v), power(n), energy(n), strength (n), compel (v), influence (v), might (n), and vigor (n) (Rice et al., 2004).

Native Language as a Mediator

It is a commonly held view of second language learning that the learner uses the semantics of the native language as the foundation. The student's resulting ability to learn the context of the second language is mediated by the student's ability to understand the material in their native language. The student uses their prior knowledge of word meanings in their native language to learn the meanings of words in the second language (Jaipal, 2000; Vygotsky, 1986). In essence the native language serves as the "mediator between the world of objects and the new language" (Vygotsky, 1986, p. 161).

The use of the native language in teaching to ELLs is a fiercely debated issue, but many researchers agree that implementation of the native language in the classroom clearly impacts the success of ELLs (Ramos, 2001). Krashen (1996) believes the use of the native language in the classroom provides ELLs with a foundation for the acquisition of new knowledge and improved literacy. In developing these two factors in combination with content-rich English instruction, English language acquisition is accelerated. In a study by Gersten and Baker (2000), research showed that the strategic use of native language for describing more complex science concepts and understanding challenging contexts provided ELLs with a greater chance for success, although the researchers later stressed against providing dual translations for vocabulary. Other research in second language learning also supports the theory that meanings underlying words in the first language mediate second language learning as a means of translating words to the second language (McGroarty, 1992), while other studies clearly show evidence that vocabulary may not always be translated appropriately, or used as a mediator between native and second language, especially in the science classroom (Jaipal, 2001).

Jaipal (2001) concluded from an eight month case study of ELLs in a grade 11 biology class that prior knowledge of concepts in the native language was not always directly transferred to the second language, and challenged the notion that the child only needs to acquire a new label in the second language for an already existing concept. In one example, a Spanish-speaking student explained how she had difficulty understanding the relationship between the term "earlobe" to the shape of a Gingko Biloba leaf (see Figure 1).

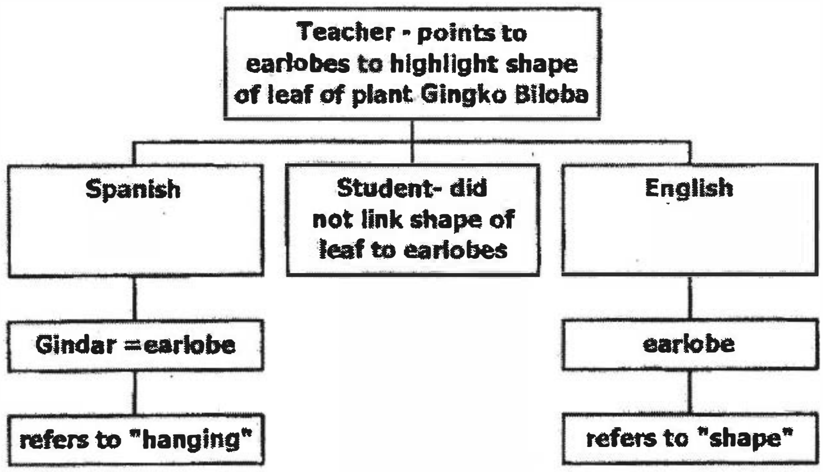


Figure 1. The Gingko Biloba Teacher - Student Interaction (Jaipal, 2001, p.9).

Figure 1 suggests a partial overlap of meaning between the native and second language, which emphasizes different features of the words "earlobe" or "gindar" (Jaipal, 2001). In this study Jaipal further examines the way in which specialized scientific terms are formed through what Halliday (1998) defines as the nominalization of words. Scientific language has evolved through the nominalization of verbs, or in other words turning verbs and adjectives into nouns, to create the specific and technical language so commonly used in scientific discourse. Again, such words have little to no reference in many languages other than English, and may cause confusion when ELLs and their teachers attempt to use native language as a mediator (Jaipal, 2001).

Risk Taking and Risk Avoidance

Scientific writing can differ drastically from the generic academic essays and basic rhetorical modes of writing found in most language arts and humanities classrooms. An ELL being introduced to the language of scientific writing often lacks the skills necessary to proficiently hypothesize, examine, describe, analyze, predict, and explain scientific data in the written English language. A major descriptor of ELL future success and development of scientific writing abilities are the risk taking and risk avoidance strategies that these learners employ.

Chimbganda (2000) defines risk taking as the learner deciding "to keep to the original communicative goal but compensates for insufficient means or makes an effort to retrieve the required items" (p. 308), and defines risk avoidance as attempting to "do away with a communicative problem" (p. 308). The following examples are of two student answers from a case study (Chimbganda, 2000) of first year undergraduate ESL science students in response to a question on the advantage and disadvantage associated with the division of labor between cells and multicellular organisms:

Risk Avoidance Response

Many activities can be performed at once or at the same time. A lot of energy is needed to bring coordination of this [sic] cells together (p. 320).

Risk Taking Response

[The advantage] is to increase the efficiency or effectiveness of the systems in the body, as cells are specialized [sic] for the function they perform. [The disadvantage] is that there are a lot of activities associated with the multicellular organisms and this requires more energy. Cells of different function assist others when others are not functioning well (p. 320).

The difference between the risk taking and risk avoidance response is students' application of linguistic resources to achieve the communicative goals. The risk taking student clearly has made an effort to retrieve the required information through compensatory strategies, such as paraphrasing (i.e. 'or effectiveness of the systems in the body' or 'cells of different function assist others when others are not functioning well'). It could be argued that the risk avoidance student merely did not know the answer to the question. When the professor questioned this student about their answer, the student was able to orally answer the question but admitted to not knowing how to answer this question in a written response (Chimbganda, 2000). This raises a critical question for science teachers; should science teachers reward students for having the right idea, or reward them based on their ability to properly convey their understanding of the science concepts through the appropriate use of the English language?

According to the National Science Education Standards (NRC, 1996), a scientifically literate person must be able to "engage in public discourse and debate about matters of scientific and technological concern" (p. 13), and the risk taking student sample is clearly a better example of a scientifically literate person, than the risk avoidant student. "By focusing on the communicative approach to scientific writing, which emphasizes more 'fluency' than 'accuracy' and the 'creation of a text' over a 'form'" (Chimbganda, 2000, p. 323) students are not encouraged into risk taking endeavors in communicating their ideas so they can build upon existing knowledge of the appropriate use of the English language, specifically in the scientific form. When using the communicative approach, that fosters risk avoidance strategies in ELLs, the end results are students who lack overall communicative competence -- especially in writing skills. To improve student inadequacies, secondary science and other teachers need to go beyond the scope of the communicative approach in their classrooms, creating safe environments that foster risk taking from ELLs in their spoken and written applications of their second language (Chimbganda, 2000).

Graphic Representations and Visual Aids

Graphic representations may range from complex semantic maps to simple pictures correlated with specific terminology to word walls, but regardless of the nature the general consensus among researchers, teachers, and ELLs agree on their usefulness in creating deeper understandings in abstractions of the scientific language and concepts. The selection of the words should be carefully considered and the number of words students are expected to learn at one time is an important component for deepening understanding of word meanings and sustaining vocabulary growth. Words of high utility that are central to the subject or concept being taught, and are meaningful to the lives of the students provide for the best choices. The traditional method of providing students with twenty or more words is no longer considering a beneficial teaching method, instead current research recommends using as few as seven words or less and spending more time discussing the terminology and explaining the context in which it is used (Gersten & Baker, 2000). Rather than spending major chunks of instructional time memorizing lists of new terminology in science classes ELLs can derive more meaning from vocabulary instruction when teachers develop ideas about how the terminology is used, where students actively participate in activities, such as inquiry, that make the terms more memorable and applicable to their lives (Faltis & Arias, 1993).

Gersten and Baker (2000) identify two intervention studies (Rousseau, Tam, & Ramnarain, 1993; Saunders, O'Brien, Lennon, & McLean, 1998) that incorporated the use of visual aids for teaching vocabulary, such as words written on the chalkboard, concept maps, pictures, word banks, and graphic organizers. In both studies researchers found the implementation of visual aids to directly increase student learning of vocabulary, reading skills, and language arts skills. Researchers observed that the use of visual aids gives students, especially ELLs, a concrete representation of the often times abstract, vague nature of the spoken language.

Sentence and Summary Framing

As Carrier (2005) observes one of the most common mistakes teachers of ELLs make when defining objectives for science literacy is to set the focus upon vocabulary acquisition and fail to consider the structure in which that vocabulary is used. In order for most ELLs to be able to appropriately use new scientific vocabulary they need to know descriptive vocabulary and how to use that vocabulary with particular language functions. For example, in order for an ELL student to properly describe a cell, the student needs to know descriptor words, such as rectangular, smooth, and irregular, as well as the parts of the cell (chloroplast, vacuoles, nuclei, etc.). The next step is to give the students an outline to aid them in building grammatically correct and fully formed sentences. One strategy is to use sentence frames that are templates of language functions where students can insert the appropriate vocabulary terms. Carrier (2005, p. 8) provides the following examples:

It looks like ________ . They are shaped like _________ .

Animal cells are like plant cells because _____________________ .

First, I ___________________________ . Next, I _______________ .

By using sentence frames, students are still involved in critical thinking and inquiry skills, but they are also learning how to use vocabulary in a grammatically appropriate fashion. As learners develop their scientific writing proficiency sentence framing can slowly be withdrawn until it is no longer necessary (Carrier, 2005).

Another strategy similar to sentence framing is called Summary Frames (Honnert & Bozan, 2005; Marzano, Pickering, & Pollock, 2001), which requires a higher level of thinking from students and is proven to be a highly beneficial tool in teaching to ELLs. The Summary Frame strategy includes various models, such as Definition Frame, Problem/Solution Frame, both of which lend themselves very well to science instruction. In these models the teacher asks, either written or oral, a series of planned questions to the ELL with the purpose of creating a brief summary by the end. Marzano et al. (2001) provide these examples of a Definition and Problem/Solution Frame, respectively:

Definition Frame:

What is being defined?

To which general category does the item belong?

What characteristics separate the item from other things in the general category?

What are some different types or classes of the item being defined?

(p.38)

Problem/Solution Frame:

What is the problem?

What is a possible solution?

What is another possible solution?

Which solution has the best chance of succeeding? (p.40)

Once the questions have been answered the student can piece them together to create a brief summary paragraph. Honnert and Bozan (2005) concluded that the Definition Frame works well when introducing new scientific vocabulary, such as at the beginning of a unit, while the Problem/Solution Frame works well with laboratory exercises.

Inquiry-based Activities

In order for students to fully understand science they must first understand that science is an intellectual and social endeavor that requires something more than just technical competence. The Benchmarks for Scientific Literacy (AAAS, 1993) state that, "acquiring scientific knowledge about how the world works does not necessarily lead to an understanding of how science works, and neither does knowledge of the sociology of science alone lead to a scientific understanding of the world" (p. 3).

Students must engage in activities of authentic scientific inquiry in order to completely realize the nature of science and how it distinguishes itself from all other ways of knowing in its empirical standards, logical arguments and skepticism of existing explanations of the natural world (Hand et al. 1999).

For the ELL student in the science classroom the nature of science and inquiry can be the key to unlocking the mysteries of the scientific language. Inquiry affords students the opportunities to not only learn the technical vocabulary, abstract concepts, and processes of the natural world but also to use and experiment with the scientific language by describing observations, inferring, constructing explanations, asking questions, and communicating results to others. Inquiry science affords ELLs the opportunities to engage in activities that are hands-on and interactive with concepts that are built through manipulating the materials, prior knowledge, and verbal interactions with peers. More importantly, in the general education science classroom inquiry science is inclusive rather than exclusive, or student-centered rather than teacher-oriented, respectively (Hampton & Rodriguez, 2001). Student-centered, inquiry activities create an open, interactive environment that provides ELLs greater opportunities for meaningful language exchanges with peers and teachers while ELLs are often times disengaged from meaningful discussion and use of the English language in a teacher-centered classroom.

Writing in Science

The interactive learning experience involving exploration of new ideas, problems, challenges, and alternative solutions promotes students not only talking science, but also writing science. Hand et al. (1999) explain how "writing in science is conceptualized as a process that develops reasoning, inducts into the discourse of science, and promotes personal meaning making in relation to scientific explanations" (p.1028). Huang (2004) argues if the integration of language and content is to be made explicit for ELLs, then instructional objectives must intersect both subject area content knowledge and language development, and scientific writing can be used as a tool to bridge this gap.

In a case study of 23, grade 8-10 ELL science students Huang (2004) develops an instructional method for integrating writing as a tool for socializing ELLs with secondary school science. This method follows seven sequential stages, shown in Figure 2, aimed at designing, editing, and producing a revised final draft of scientific writing that is representational of simultaneous content learning supplemented by prior instruction using graphic organizers, concept maps, and visual representations of concepts. From the analysis of this study Huang measured an increase in the number of terms explained through definition or description, a higher degree of content elaboration, and a change in the quality of explanations from the first to final drafts providing evidence that academic content learning can be coupled with academic writing.

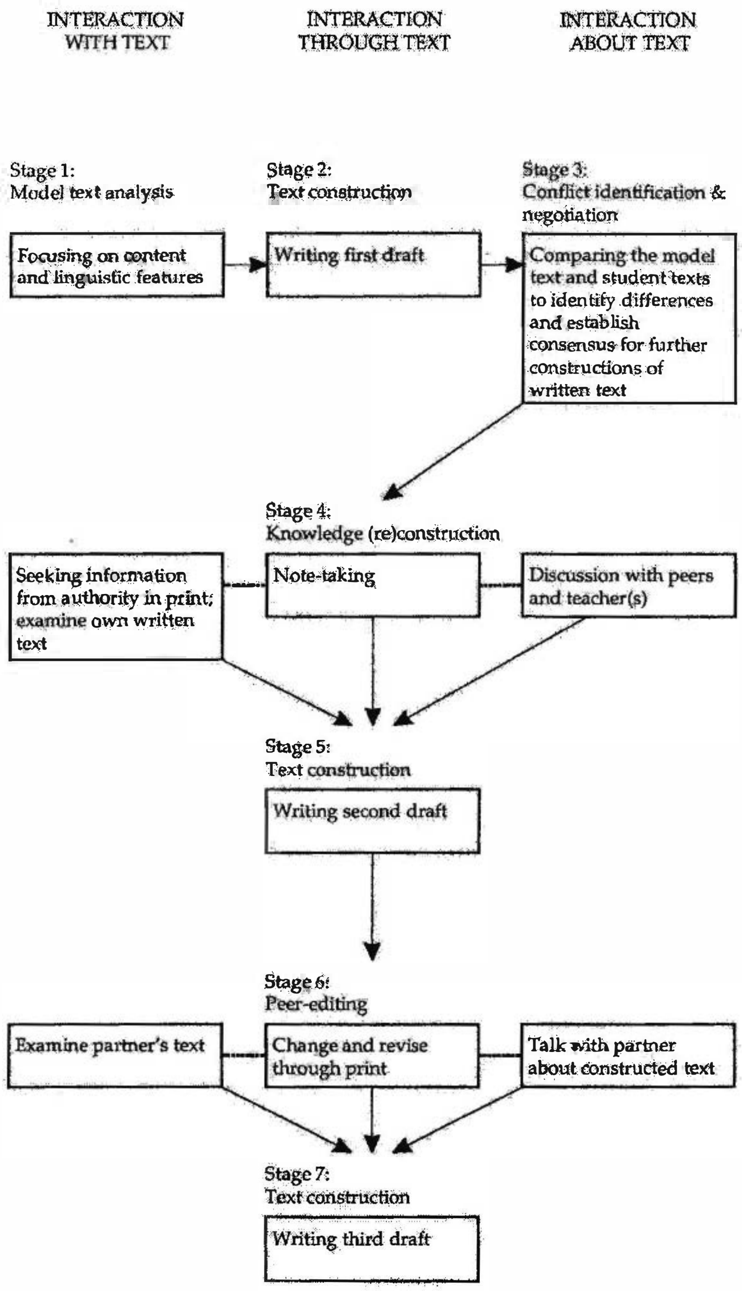


Figure 2. The Instructional Process used to integrate writing as a tool for socializing ELLs with secondary school science (Huang, 2004, p.108).

Chapter Three: Applications and Evaluation

Introduction

The main objective of this study was to test multiple instructional aids and learning strategies for teaching science to ELLs, and to report on the successes and failures of such aids/strategies implemented in this study. Another objective of this study was to provide additional support beyond regular classroom instruction to an ESL student in a Regents Earth Science class, aimed at improving this student's understanding of technical vocabulary specific to the curriculum, and improving scientific writing skills commonly incorporated into lab exercises.

Participants

The sole participant in this study was a 10th grade ESL student taking Regents Earth Science. The classroom is an inclusion setting with a small percentage of students with IEPs for varying disabilities, such as ADHD (Attention Deficit Hyperactivity Disorder) and Learning Disabilities. As previously mentioned, the student participant was a previous student from my student teaching experience, whose parents had inquired about extra support beyond what her science teacher and the school could provide. The student came to America in the third grade, has always been in a general education classroom, and has received ESL support ever since in the form of a resource room. When she came to America neither she, nor her parents were able to speak even functional English, and presently she is the only person in her family to have learned the language.

Procedures of the Study

For the purposes of this study I designed tutoring style sessions that meet once every four-day school cycle, lasting for approximately two hours in the school library during the student's free period. Each session was designed differently, working off the curriculum currently being taught in the student's earth science class, and the homework and lab exercises assigned. The sessions were split into two inter-related sections; the first consisted of planned writing and vocabulary exercises that use various strategies and aids for developing scientific vocabulary and writing skills, and the second section incorporated these strategies and aids into the student's current class work and assignments. In essence the sessions served a two-fold purpose: (a) to assess the validity, applicability, and success of specific strategies and instructional aids in teaching science to ELLs, and (b) to provide additional support to an ESL student that could not be provided under normal circumstances by the student's school or teacher.

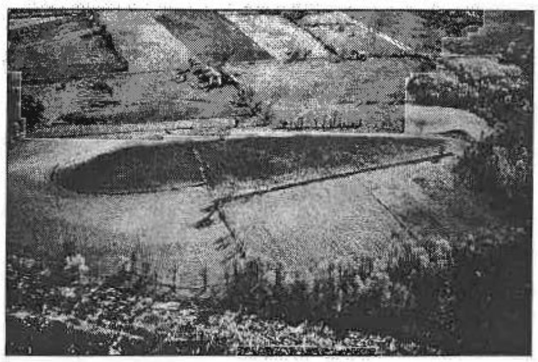
Before I could design appropriate instructional exercises I had to assess the student's abilities and weaknesses. Using my prior knowledge of the student's class work, including lab write-ups, homework assignments, and class participation, I was able to gain a moderate understanding of the student's struggles within the earth science classroom. I further reviewed past lab write-ups and interviewed the student about her perceived strengths and weaknesses, and asked her what she would like to come from the tutoring sessions.

Instruments for Study

The basis for the instruments used in this study came from prior research, such as summary frames, adapted from Marzano et al. (2001) and Honert & Bozan (2005), while other instruments incorporated new ideas into strategies long used by educators, such as the vocabulary lists with images gained from the internet. Other instruments used in this study include interviews with and feedback gained from the student prior to and during the tutoring sessions, and previously completed lab assignments, homework, tests and quizzes, and class work I reviewed in order to design the tutoring sessions and summary frames.

I used various visual aid strategies for vocabulary building during the tutoring sessions, including concept maps and graphic representations of definitions for technical, and possibly confusing or misleading terms. For creating graphic representations of definitions I used Google Images (Google, 2006) and Wikipedia (Free Software Foundation, Inc., 2002) to search for appropriate pictures to match new terms, as well as terms from past units that the student had identified as terms she never gained a proper understanding of. As a supplemental studying strategy I had the student write the terms and definitions on opposite sides of index cards. Table 1 provides a few examples of graphic representations created as a part of this study (for more examples see Appendix A):

Drumlin:



Ventifacts - wind carved rock:

Figure 3. Vocabulary terms excerpted from vocabulary worksheets used during tutoring sessions.

The sessions further built off using these vocabulary strategies by incorporating them into writing exercises with the goal of using increased numbers of terms in an appropriate and grammatically correct fashion. For the first half of the sessions summary paragraphs were used as a scientific writing exercise, while lab write-ups and homework assignments were used to incorporate technical vocabulary in the second half of the sessions.

When I reviewed the student's previous work from short answer and essay questions on unit assessments, short answer homework assignments, and lab write-ups I was able to conclude that a major barrier the student faced was an inability to construct a summary from a large pool of information, often found in a lab exercise. Summaries often seen on homework assignments and unit assessments, including the NYS Regents Exam, require the student to identify key facts, definitions, and concepts from a large body of information, possibly a large paragraph (7-10 sentences) or up to many pages, while identifying unimportant or negligible information that does not need to be included in the summary. Next, the student must reorganize these facts, definitions, and concepts into his/her own words, a skill that ELLs often find troubling (Honert & Bozan, 2005; Huang, 2004; Jaipal, 2001).

Using the summary frame concepts suggested by Marzano et al. (2001) and Honert & Bozan (2005), I was able to construct a summary frame tailored specifically to a secondary science class, and more specifically to earth science (see Appendix B). At first I designed very specific summary frames for a few writing/reading exercises (see Appendix C), given for the purposes of the study only, in an attempt to gain a better understanding of how I could design a summary frame that would be universally applicable to all homework assignments and unit assessments.

The summary frame exercises were a three-part process, which enabled me to assess the student's ability to construct a summary prior to and after being provided a summary frame, and to assess the success of the design of each summary frame. The three-part process began with the student reading a two paragraph or more passage from an earth science textbook. Next, the student was asked to write a 5-7 sentence summary of the passage as homework, in which case I would not be available to provide insight, direct her, or answer any questions, and she would not be under any time constraints. Then, in the next session I would provide the student with a summary frame tailored specifically to the assignment, again asking her to construct a 5-7 sentence summary, but this time she was given 30 minutes to complete the task during the tutoring session. Table 1 is an excerpt from one of the summary frames used on chemical weathering:

Define chemical weathering (see pg. 131).

What are the four main ways that chemical weathering may occur in rocks?

1.

2.

3.

4.

Table 1. Excerpt from the Chemical Weathering Summary Frame (also see Appendix C).

Lab write-ups differ greatly from these homework and assessment summaries in both their content and structure. The district I was working in uses a very standardized and formal structure for lab write-ups, which are required by the district for any formal laboratory experience. All teachers and students must use this standardized, district lab format, called a C.E.I. write-up (Claim, Evidence, and Interpretation). The Claim usually refers to the purpose or objective of the experiment and students are often told to re-state the purpose from the lab handout. The Evidence must contain one observation and one piece of numerical data that provides evidence to accept or reject the hypothesis, and the Interpretation must include a valid source of error, a real-life application, or an extension of the experiment.

I designed a C.E.I. outline summary frame that is applicable to the C.E.I. lab write-up format with the objective to make the student less dependant upon using things such as the stated purpose in the lab handouts to complete the claim. It also provides a structure for the student to identify the hypothesis, organize key pieces of evidence, and formulate real world applications and extensions. Also, it is designed so that each question in the summary frame can later be plugged into paragraph form by copying from the outline sequentially. With many of her incomplete and missing labs we were able to apply the outline in a way to revise each lab, which also provided a reference for me in assessing the practicality and validity of the C.E.I. summary frame.

Chapter Four: Results

By reviewing numerous lab write-ups completed prior to the tutoring sessions and comparing them with lab write-ups completed during the tutoring sessions I was able to assess the tutoring session methods (i.e. the use of graphic representations combined with summary frames and C.E.I. outlines). I also used feedback from the student participant gained throughout the study, as well as my own observations of student achievement, struggles, and work habits to assess the successes, or failures, of the instructional strategies used.

During an interview the student participant stated that she "gets frustrated during lectures because [she] can't understand most of the words," believes that she "understands English well and understands well in other subjects, like social studies and English," and "copies off of other students at [her] table during labs and class work a lot because [she] doesn't understand what [they] are doing." The student identified three major weaknesses she would like strengthened as a result of the tutoring sessions, which included "understanding vocabulary words" given at the beginning of each unit, "getting better grades on [her] labs and not getting so many of them turned back for corrections," and gaining a better understanding "of what [they] are doing in class." For vocabulary comprehension I was able to determine two major struggles: (a) the inability to translate many technical words from the English language into the student's native language, and (b) dual word meanings of many technical terms (i.e. reverse *fault*, tectonic *plate*). Student struggles defined for writing skills, mostly through reviewing prior writing assignments, included: (a) sentence chunking, (b) topic avoidance (Chimbganda, 2000), (c) an inability to fully comprehend the objectives of writing assignments, (d) vocabulary comprehension deficiencies, which prevented the student from being able to properly apply appropriate science terms to the writing assignments, and (e) summary skills, often used in lab write-ups and short answer questions on unit assessments.

For an ELL in an earth science class most of the vocabulary is untranslatable to their native language, especially those coming from countries whose native language is not Latin-based (i.e. Russian, Ukrainian, and Mandarin), and word meanings become misinterpreted, confused, and eventually misused. The student participant from this study explained that she still, even after eight years' experience with the English language, continues to process both oral and written English in her native language, but when given earth science terms such as eccentricity, aquifer, and drumlin she fails to find adequate, if any, translations into her native Ukrainian language. Furthermore, other terms such as exfoliation, mudslide, and strain can have dual meanings, misleading definitions, or earth science-specific definitions that may only be found in specialized dictionaries. Many of the definitions even found in the earth science textbooks tend to be technical in their explanation of the terms, and only a few can be found with correlating diagrams, pictures, or other visual aids within the text.

As previously identified, this student often struggles not only with vocabulary skills and summary skills but also with comprehending objectives of writing assignments. Prior to the tutoring sessions many of her lab assignments were missing or incomplete, and the assignments that had been handed in were of poor quality; containing many misused terms, sentence chunking, and showing little to no comprehension of the purpose, findings, or applications of the experiments. I needed to know if the student truly lacked knowledge in what the labs were about, or if her major trouble was expressing what she knew in the written language. I asked the student to bring in two or three of her most recent labs she had not handed in to a tutoring session. I asked her to explain to me, orally, the Claim, some Evidence, and the Interpretation. I found that she knew what had happened during the lab, she could explain the steps taken and the findings, but her greatest struggle was defining the objective for the lab. Most labs come with a handout page that defines the purpose, procedure, and sometimes offers a few conclusion questions. Students are told to re-state the purpose of the lab in completing the claim section of the C.E.I., but the purpose does not always fit a claim, in which case the students must come up with a one sentence claim that summarizes the entire experiment. I discovered that she would often use the stated purpose and did not understand why it would not fit as a claim, and was unsure as to why the lab needed to be fixed when it was handed back from the instructor. In many of these cases, due to her frustration, she ended up receiving the labs back to correct and never turned them in again.

Data shown in Figure 4 describes the amount of appropriately used vocabulary terms in each of five labs that had been revised during the tutoring sessions. Appropriately used vocabulary is defined as any scientific term used in the proper context of its definition or meaning, in conjunction with proper grammatical structuring within the sentence and paragraph. Each of the five labs had been previously turned in, but handed back to the student for revisions for one or more of the following reasons: (a) incomplete C.E.I., (b) too many grammatical errors in the

C.E.I., including sentence chunking, (c) or failure to show adequate understanding of the experiment in the C.E.I. portion of the lab write-up. The first step was to discuss vocabulary terms found in the labs using graphic representations, followed by a discussion of the procedures of the experiment. Next, the student was given the C.E.I. outline summary frame to complete the revised version of the C.E.I.

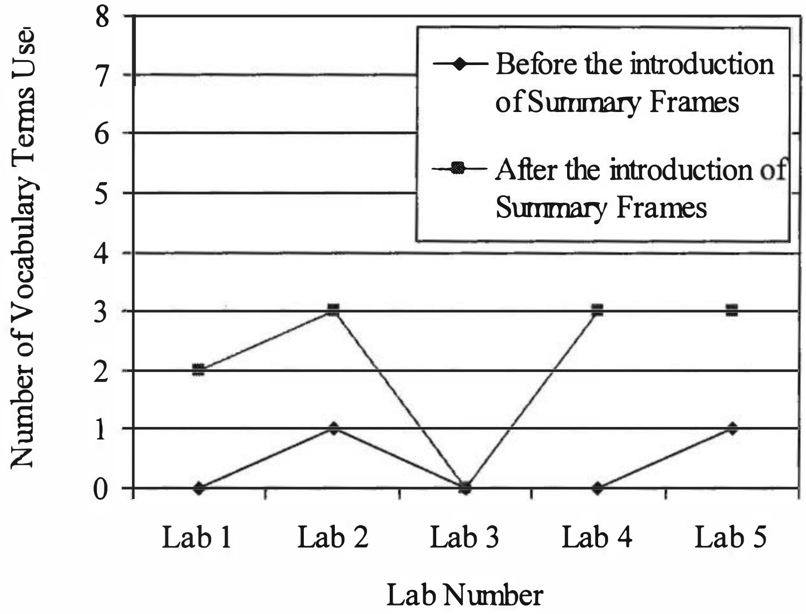


Figure 4. Data comparing the number of appropriately used lab-specific vocabulary terms pre- and post-summary frames in the lab writing process.

Figure 4 shows a remarkable increase in the number of vocabulary terms specific to the experiment that were used in the revised versions of each lab, with the exception of Lab 3. The exception of Lab 3 can be accounted for due to a lack of lab-specific vocabulary terms. The lab experiment dealt with reading a geographical map of Africa and its annual distribution of precipitation. The only scientific term that could be used in the C.E.I. was precipitation, which I discounted from the data because the term had been previously introduced many times during the course of the year and was a familiar term for the student.

I later asked the student for her insight on the effects the graphic representations and vocabulary discussions had on her ability to use the words in lab write-ups, in which case she explained that the visual aids greatly helped her understand the terms. The images provided her with a mental picture of what these terms meant and enabled her to define the terms in her native language before attempting to use them in English.

This study was not only designed to improve the basic scientific vocabulary skills of ELLs but also to define strategies that could be used to enable better scientific writing skills overall including decreasing the use of sentence chunking and increasing grammatical and summary skills. Grammatical skills, such as the use of commas, verb tense, and the use of pronouns to name a few, were often addressed during discussions that took place in the revision processes noted previously, but not quite as often on newly assigned labs. To assess the success of summary frames on the student's ability to construct adequate summaries with decreased sentence chunking and the use of proper grammatical devices the grades given by the student's earth science teacher on lab reports were analyzed. The student's teacher was not involved in the tutoring sessions, and therefore impartial to the methods being tested and outcomes being assessed. Each lab is graded out of ten possible points, with the C.E.I. being the major contributor to the grade. Other variables taken into account for the grade include proper construction of graphs relating to the lab, proper labeling of maps, diagrams, or pictures, and the completion of conclusion questions related to the lab. For the purposes of this study only the C.E.I. paragraphs were worked on and discussed during the tutoring sessions.

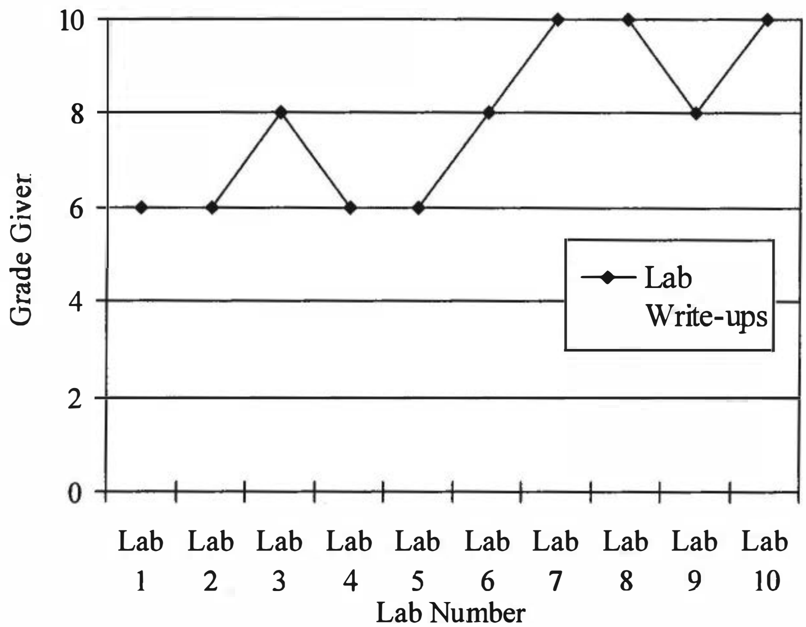


Figure 5. Lab grades given prior to and during the tutoring sessions.

Labs 1-5 in Figure 6 were completed by the student prior to this study without the use of summary frames or additional support, while labs 6-10 were completed during the study using summary frames supplemented by discussions on the lab material. Figure 5 shows a direct increase in ten lab grades from labs 1-5 to labs 6-10, providing evidence supporting the effectiveness of the use of summary frames with this student when completing tasks involving the application of summary skills.

When I asked the student for feedback on the applicability of the summary frames and their effect on her recent successes on the labs she said she would continue using the C.E.I. summary frames, and that she believed they would help her even without the aid of the tutoring session discussions on vocabulary and grammar.

She also said that the summary frames helped her to create a more acceptable paragraph structure because she can fill in one question at a time on the summary frame, then go back and sequentially copy each answer to form the C.E.I. paragraph. The summary frame provided a structure for her, and allowed her to organize her thoughts one sentence at a time.

Another variable I observed during the course of the study was the student's frequency to use a topic avoidance strategy (Chimbganda, 2000) in answering questions on homework, lab conclusions, and other written assignments. In such scenarios the student either chose to skip questions altogether, although she clearly knew the answer but had trouble expressing, or provided an often lengthy answer in hopes of hitting on something relevant to the topic. Topic avoidance is a risk-avoidance strategy defined by Chimbganda that often provides low levels of success in the classroom. On many homework assignments the student skipped multiple questions she did not know how to answer in English, or could not understand. This student often chose not to attempt answering questions once she became frustrated or confused; a form of topic avoidance, which provides the least likely opportunity to succeed. If she had tried answering the questions she would have had a chance to gain points on assignments, but due to her lack of attempt she was often marked incomplete on the assignments. Through the course of the study, the student showed a marked decrease in her use of topic avoidance strategies, as she became more fluent in the language of earth science and her vocabulary and summary skills were improved upon. Consequently, fewer homework assignments were being handed back to her as incomplete, and her teacher also commented on a drastic improvement in the quality of such assignments. Although improvements were seen in lab and homework grades, the student failed to make notable improvements on her exam and quiz grades during the course of the study. In fact, the student's unit assessment grades dropped slightly. This could have been a result of the units that were being covered for the majority of the study: rocks and minerals. The amount of untranslatable rock and mineral names, identifiers, and characteristics introduced, and heavily relied upon, during these units could have caused a great deal of confusion and misunderstanding for the student, which could have been a major contributor for declining exam and quiz assessment grades during the study.

Chapter Five: Conclusions and Recommendations

Discussion

Current literature and theories on ESL learning suggest increased success from such students in classrooms with small teacher to student ratios, where supplemental aids are used when introducing terminology, engaging students in higher order tasks, and during writing assignments. This study provides more evidence to the growing wealth of research that supports the use of such instructional strategies and aids when teaching to ELLs in the science classroom. Supplemental aids and instructional strategies, such as Summary Framing, graphic representations for technical vocabulary, and 1:1 tutoring sessions showed improved student performance on assessments and a marked increase of student understanding over a brief period of time. Implementation of such aids and instructional strategies into the general education classroom coordinated with the development of long-term tutoring programs for ESL students may provide an even greater insight to their applicability and practicality, while serving the needs of these students to succeed in the general education classroom.

Action Plan

The results of this study lend support for the usefulness of tutoring programs for all students in all subjects. The greatest factor in the study was increased contact time between teacher and student with regards to the material being learned. Increased contact time in a low teacher to student ratio provided a more comfortable and open environment for the student to ask questions and explain her frustrations free from peer judgments. She often told me that she would not ask questions in class because she didn't know how to ask the question properly or felt that the question may be considered unintelligent. She was too embarrassed to ask many questions in class, but during the tutoring sessions she felt comfortable enough to ask any question that came to mind.

Peer-tutoring programs could be created to facilitate these recommendations in an affordable manner in most schools. Upper classmen, especially those in AP (Advanced Placement) programs, could be used to fulfill required volunteer work, for college resume-building, or even be minimally paid as peer-tutors for students looking for extra support. Programs could meet once a week with tutors from all subject areas, or even possibly having tutoring programs meeting on different days of the week depending on the subject. A teacher mentor would also be required for the peer-tutoring programs, and more than likely an administrator would need to be involved, or at least consulted, especially if students are being paid. The length of the tutoring sessions should be at least one half hour in length, but anywhere from a half hour up to an hour and a half would be recommended. In this fashion the peer-tutoring programs would serve a two-fold purpose by providing additional support to struggling students in all subject areas that may not be available to them by their teachers, and it would provide an outlet for advanced or gifted students to develop leadership and community building skills within the context of the school community.

The results and recommendations of this study will be shared with the district staff and science teachers of the school I was working in, as well as with my own peers during a presentation. I plan to discuss the results and recommendations of this study to the science department at the school I was working in to provide them with the same insight I gained through this research. The results of this study may also be shared with other educators through action research networks and science education literature.

Recommendations for Future Research

The results of this study are narrow in focus and lack the range for any great generalizations, but they do provide insight into the applicability and use of specific instructional support mechanisms for ELLs struggling to comprehend technical vocabulary and scientific writing skills. The methods and results of this study provide the groundwork for further research at a broader scale with hopes of producing more reliable and generalizable outcomes. A participant pool of 15 or more students could provide such outcomes, while a study across schools could provide possible insight to the context of teaching ELLs from varying backgrounds – school, familial, linguistic, ethnic, and religious cultures – and the differing struggles found within each cultural context with their relationship to science education. A study of this nature would include multiple researchers possibly, at different schools, with the aid of both science educators and ESL educators. A study of this magnitude would also require funding from state, local and national agencies, foundations, and organizations to pay for research assistants, instructional materials, and possibly for teacher participants in the study.

Conclusion

According to the 2000 U.S. Census the number of non-native English speakers in the U.S. is swiftly on the rise, and as the demands for all American students, regardless of race, religion, sex, or ethnicity, to become proficient in English and science gains importance for all members of the school community (teachers, administrators, district personnel, parents, etc.). These individuals must be prepared for the future challenges in educating these students. The research conducted during this study is a small step towards identifying and resolving the issues at hand within the school community with regard for ELLs. Not only is more research needed in this field, but also more action within the school communities at providing support and programs for ELLs at all levels.

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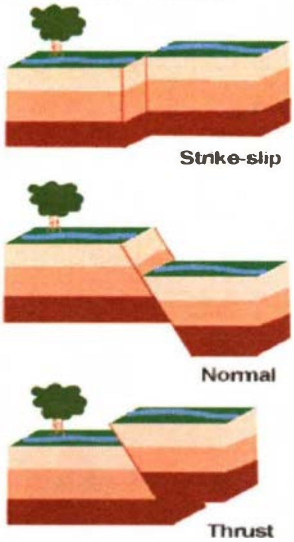
Appendix A

Earthquakes Vocabulary Sheet

Earthquake: a sudden and sometimes catastrophic movement of part of Earth's crust, usually from faulting.

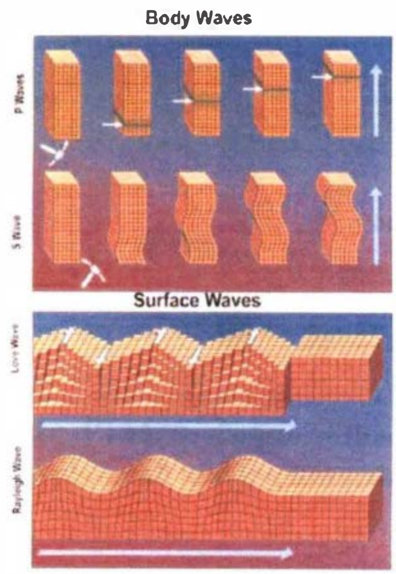
Faults: rock fractures which show evidence of relative movement; three types are normal, reverse, and transform faults



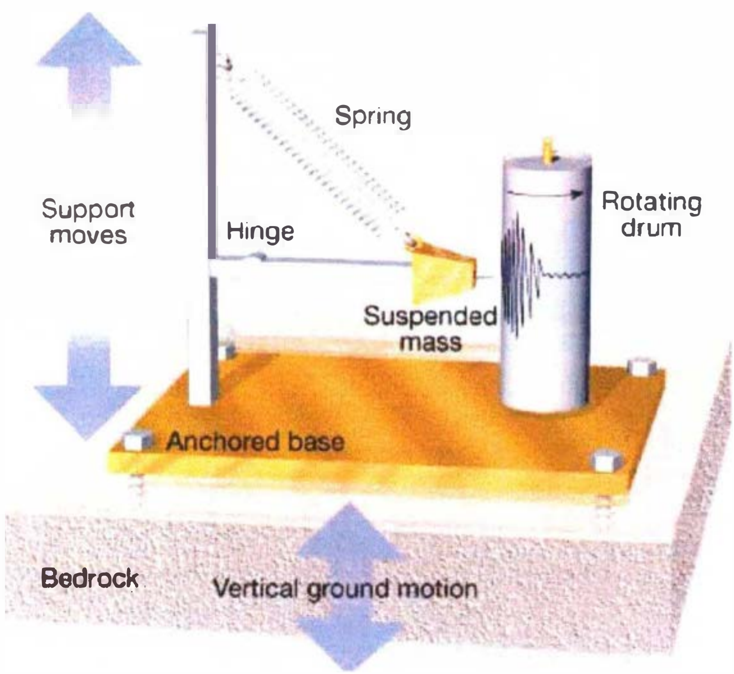
Seismic Waves: a wave that travels through the Earth; two types exist called body waves and surface waves.

Body Waves: seismic waves that travel through the Earth's interior; two types are primary waves (p-waves) and secondary waves (s-waves).

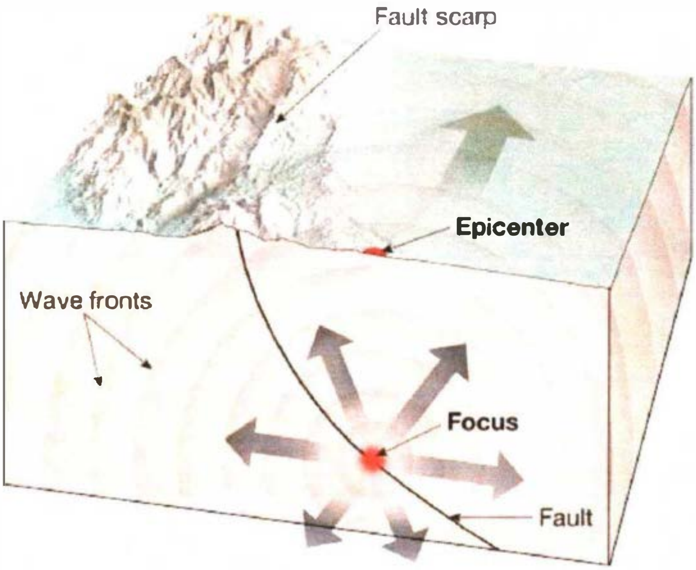
P-waves (comPressional) **S-waves (Shear)**



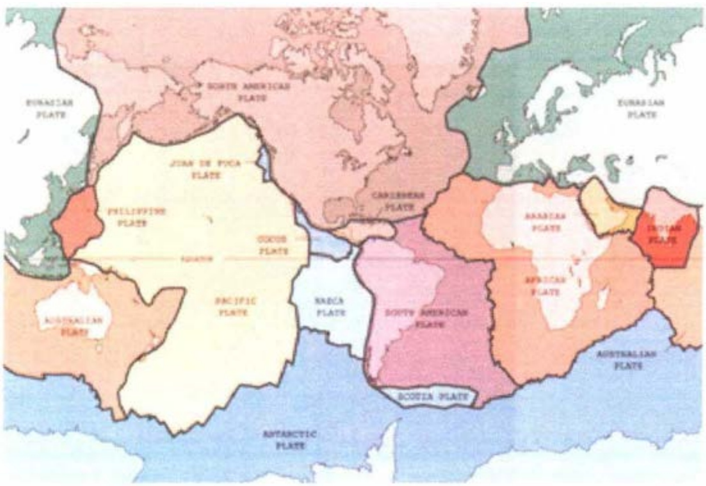
Seismograph: a tool used by geologists to measure and record seismic waves; also called a seismometer; ***seismo = earthquake, metero = measure***



Epicenter: a point on the Earth's surface that is directly above the point where an Earthquake originates.

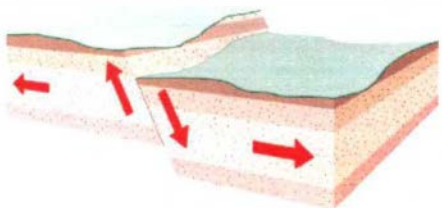


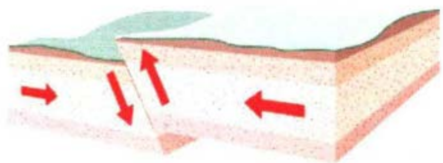
Tectonic Plates: a piece of the Earth's crust and uppermost mantle. Earth has ten major plates all moving towards and away from each other at very slow rates.

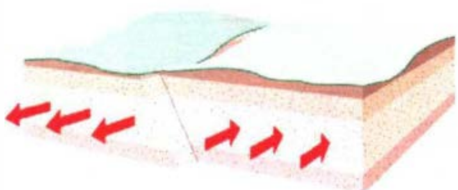


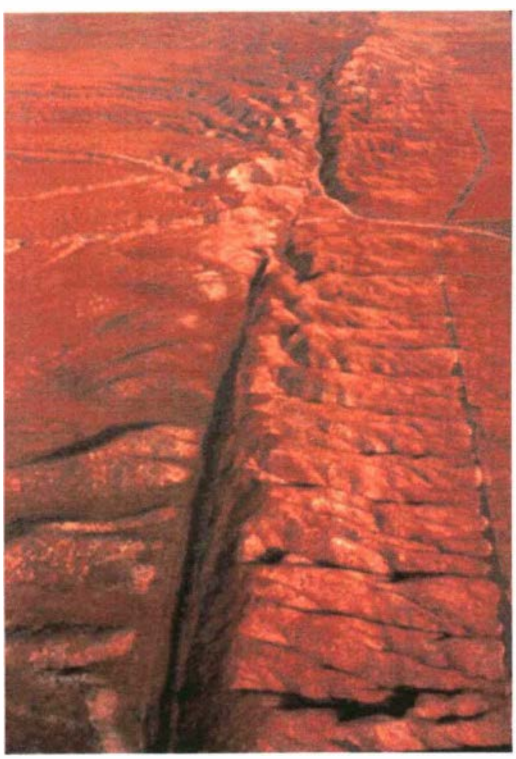
Vocabulary Review #1

Faults

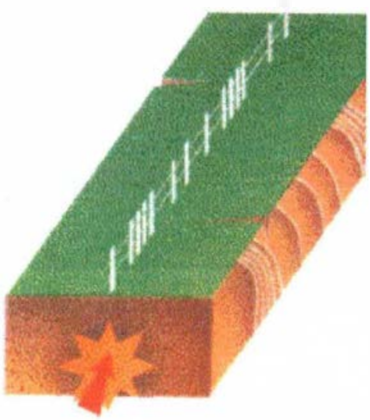




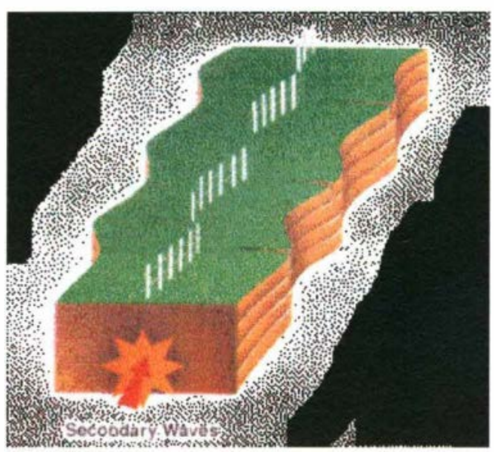


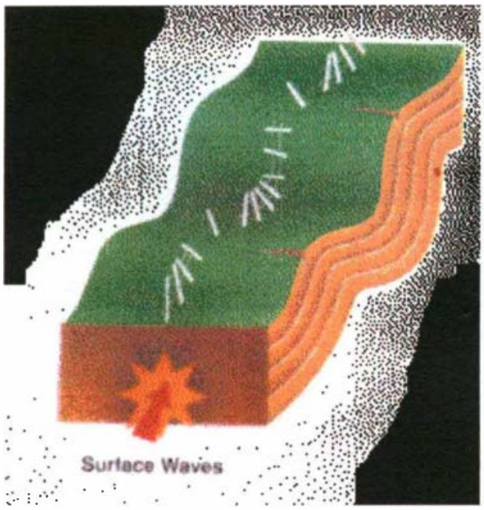


Stress/Strain



Primary Waves





Stream Erosion

Moraine

Drumlin

Ventifacts – wind carved rocks

Appendix B

Summary Frame

List 2-3 key words from the reading and write their definition next to them. (Draw a picture if needed)

1.

2.

3.

What is a major concept or process that is explained in the reading? (Example: faulting, or chemical weathering)

Use the key words and their definitions to explain this concept or process. How does it work?

Is there an example of this concept or process seen on Earth? Explain. (Example: transform faulting observed at the San Andreas Fault in California)

Appendix C

Chemical Weathering Summary

Directions: In the **Earth Science** brown book, read **Topic 4: Chemical Weathering** on pages 134-135. Complete the questions below to help you write a 4-5 sentence summary paragraph on the reading.

Define chemical weathering (see pg. 131).

What are the four main ways that chemical weathering may occur in rocks?

1.

2.

3.

4.

What is formed when carbon dioxide dissolves in water?

What is significant about carbonic acid and calcite? What are formed by this reaction?

How is acid rain formed?

Appendix D

Claim Evidence Interpretation

Lab Outline Summary Frame

A. What is a possible **hypothesis** for this lab?
Hint: Make a prediction about what you believe might happen as a result of the experiment.

B. What are two pieces of evidence you found in this lab? (Evidence may come from graphs, charts, observations, etc. – try using numbers)
Ex.: The data shows that location A receives 12 hours of sunlight/day in June, while location B only receives 9 hours of sunlight/day during the month of June.

1.

2.

C. **Claim**
Write a claim for this lab that describes the objectives. *Hint: Try reading the procedures first*
Ex.: From this lab we were able to determine that soil has a lower specific heat than water.

Evidence

What is the evidence that supports your claim?
Use the questions from section **B.** Be sure to include at least one piece of evidence using numbers from the data table, a graph, or a chart.

Interpretation

Answer at least **ONE** of the following questions:

How would someone use this information in the real world?
Ex.: Miners who are looking for a certain mineral need to know about local geology and bedrock.

How could we extend this lab?
Ex.: We could study the sun's path in the sky at the beginning of the school year and the end of the school year.

What were some sources or error in this lab?
Ex.: It was raining out when we tried using the sling psychrometers outside, so we weren't able to get accurate readings of the dry bulb and wet bulb temperatures.